OBSERVATIONS ON BATRACHOSPERMUM (RHODOPHYTA) IN SOUTHEASTERN WISCONSIN STREAMS

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Knowledge of the genus *Batrachospermum* (Rhodophyta) in Wisconsin stems mainly from the report of Prescott (1951) who records four species from lotic environments without reference to locality and with only scant ecological data. Moreover, information on seasonal periodicity and environmental conditions of the type obtained by Dillard (1966) in North Carolina, Minckley and Tindall (1963) in Kentucky, and Rider and Wagner (1972) in Pennsylvania apparently is lacking for Wisconsin. (The last reference includes a literature review of *Batrachospermum* ecology.)

The present investigation has been undertaken to gain information on 1) the occurrence of *Batrachospermum* in southeastern Wisconsin streams and 2) the environmental conditions present at localities where this taxon grows. During the course of the study 201 randomly selected stream localities have been visited; *Batrachospermum* plants occurred at 13 or 6.4% of these sites.

MATERIALS AND METHODS

At each station (Table 1) where *Batrachospermum* plants were found, chemical and physical data on alkalinity, carbon dioxide, hardness (calcium and total), nitrate nitrogen, orthophosphate, oxygen, pH, temperature, and turbidity have been gathered using a Hach Water Analysis Field Kit, model DR-EL, which employs microadaptations from the "Standard Methods" handbook (American Public Health Association 1965). In addition, some observations on the type of substrate, relative current velocity, and relative exposure to sunlight have been made.

At stations where *Batrachospermum* populations persisted for extended periods, observations were made at 4-6 week intervals for 10-11 months to note any seasonal changes.

TABLE 1

LIST OF *BATRACHOSPERMUM* LOCALITIES, DATES SAMPLED, AND LOCALITY ABBREVIATIONS USED IN TEXT DISCUSSION

Text Abbreviation	County	Locality	Dates
B	Walworth	Bluff Ck, T4N, R15E, S23 at Co. Hwy P crossing	7.VI.1972
BE	Dane	Black Earth Ck, T7N, R7E, S2 along U.S. Hwy 14	15.VII.1972, 12.XI.1972, 9.i.1973
F	Walworth	"Fontana Ck", T1N, R16E, S11 at St. Hwy 67 crossing	7.VI.1972, 11.VII.1972, 3.XII.1972, 7.I.1973, 3.II.1973, 10.III.1973, 17.IV.1973
J	Manitowoc	Jumbo Ck, T21N, R23E, S26 at unnamed town road crossing	22.VII.1972
K	Sauk	Koshwego Springs, Devils Lk. St. Pk, T11N, R6E, S23	31.V.1972, 5.VII.1972, 9.XI.1972, 6.XII.1972, 5.I.1973, 9.II.1973, 10.III.1973, 17.IV.1973
M	Dane	Merrill Springs, Lk. Mendota, Madison, T7N, R9E, S18	11.V.1972

TABLE 1 cont.

MC	Iowa	Mill Creek, T7N, R3E, S35 at Twin Valley Lks. Road	3.VII.1972
N	Sheboygan	Nichols Ck, T14N, R21E, S18, at Cedar Lane Rd Crossing	23.VII.1972
Q	Washington	Quas Ck, T11N, R19E, S25 at U.S. Hwy 45 junct with Co. Hwy. NN	15.VI.1972
SC	Waukesha	Scuppernong Ck, T6N, R17E, S36 at U.W. Field Station near Waterville	5.VI.1972, 10.VII.1972, 5.VIII.1972, 17.IX.1972, 4.XI.1972, 2.XII.1972, 6.I.1973, 4.II.1973, 3.III.1973, 16.IV.1973
SR	Waukesha	Scuppernong R., T6N, R17E, S34, near junct of St. Hwy 67 and Co. Hwy 22	5.VI.1972, 7.VII.1972, 5.VII.1972, 17.IX.1972, 2.II.1973
SS	Waukesha	Scuppernong Spring, T5N, R17E, S3 along St. Hwy 67	17.IV.1972, 10.VII.1972
T	Racine	Tichigan Ck, T4N, R19E, S15 at Ranke Road crossing	13.VI.1972, 10.VII.1972, 2.VII.1972, 17.IX.1972, 29.X.1972, 8.XII.1972, 7.I.1973, 3.II.1973, 3.III.1973, 16.IV.1973

Voucher specimens from all localities have been collected and immediately preserved in FAA (10:7:2:1 95% ethanol:water:formalin:glacial acetic acid). Dried herbarium specimens (bearing numbers prefaced by WJW) and permanent microscope slides using KARO as a mountant (Woelkerling, 1970) as well as liquid preserved material have been retained in the author's personal collections, currently housed at WIS. Species determinations have been made primarily with the aid of the taxonomic key of Israelson (1942); the papers of Kylin (1912), Prescott (1951), Sirodot (1884), and Whitford and Schumacher (1969) also have been consulted.

RESULTS AND DISCUSSION

Two taxa of *Batrachospermum* found during this study have been identified to species. *Batrachospermum boryanum* Sirodot, not recorded previously from Wisconsin, occurred at seven localities (B, F, K, SC, SR, SS, T; abbreviations explained in Table 1), and with one exception (locality B), it always grew mixed with other *Batrachospermum* taxa. Sexually mature plants ranged in size from 4-21 cm with most plants averaging about 8-10 cm tall. Sexual plants have been encountered in all months except February, March, and October; further study will probably show that sexual plants do occur throughout the year.

Batrachospermum moniliforme Roth has been found at ten localities (BE, F, J, K, MC, N, SC, SR, SS, T), and has been reported previously from Wisconsin (Prescott, 1951). Except for two stations (J, N), it grew mixed with other *Batrachospermum* taxa. Sexually mature plants occurred throughout the year and ranged in length from 3-25 cm with an average height of 6-9 cm.

In addition to the above two taxa, sterile (and thus specifically unidentifiable) plants of *Batrachospermum* have been encountered at five localities (BE, M, Q, SC, T) from January-March, May-July, and in December. They varied in length from 3 cm to 15 cm. The size of some Wisconsin plants (up to 25 cm) greatly exceeds the 6 cm maximum recorded by Rider and Wagner (1972) and the 10 cm maximum found by Israelson (1942).

All Wisconsin populations of *Batrachospermum* observed during this investigation grew at or near the headwaters of spring-fed streams, thus agreeing with the findings of Minckley and Tindall (1963). Rider and Wagner (1972) also recorded their taxa from a spring-fed stream but without mention of the headwater areas. Current velocities at Wisconsin localities never dipped below 10 cm/sec and in most cases exceeded 25 cm/sec. In addition, all Wisconsin localities but one (BE) contained rocky or rocky-sandy bottoms and usually appeared free from heavy siltation and high turbidity levels.

Except for seasonal fluctuations in temperature and diurnal fluctuations in carbon dioxide and oxygen levels, chemical and physical conditions at any one locality tended to remain within relatively narrow limits during the study period. Conditions did vary considerably between localities, however, and the taxa of *Batrachospermum* encountered appear to tolerate a fairly wide range of environmental conditions (Table 2).

Of particular note is the variation in carbon dioxide levels. At no time did CO_2 levels exceed 24 ppm, and levels as low as 1 ppm have been encountered. These values are decidedly lower than those reported by Minckley and Tindall (1963) for *Batrachospermum* sp. and by Rider and Wagner (1972) for *B. vagum*, but they more or less agree with the range in values measured by Rider and Wagner (op. cit.) for *B. moniliforme*. Since both species found in Wisconsin (*B. moniliforme* and *B. boryanum*) apparently require free CO_2 for photosynthesis (Ruttner, 1960), data from the present study strongly suggest that these taxa can survive at very low concentrations of free CO_2, at least for short periods of time.

At six of the thirteen localities (B, J, M, MC, N, Q), *Batrachospermum* plants were encountered on only one occasion (Table 1), and data for three additional localities

TABLE 2

RANGE IN ENVIRONMENTAL CONDITIONS UNDER WHICH *BATRACHOSPERMUM* OCCURRED

	B. boryanum	*B. moniliformis*	*B.* spp.
Alkalinity	15-342 ppm	12-387 ppm	287-368 ppm
Carbon Dioxide	2-23 ppm	1-23 ppm	2-20 ppm
Hardness, Calcium	2-340 ppm	15-410 ppm	176-408 ppm
Hardness, Total	22-442 ppm	29-500 ppm	352-420 ppm
Nitrate	1.0-4.8 ppm	0.2-16.5 ppm	2.0-10.0 ppm
Oxygen	8-20 ppm	5-21 ppm	5-17 ppm
pH	6.2-8.4	6.7-8.4	7.2-8.2
Ortho-phosphate	0.007-4.0 ppm	0.02-4.9 ppm	0.02-8.1 ppm
Temperature	6°-18°C	1°-21°C	4°-22°C
Turbidity	0-7 J.U.	0-10 J.U.	0-15 J.U.

TABLE 3

RANGE IN SELECTED ENVIRONMENTAL CONDITIONS AT SCUPPERNONG CK. (SC) AND TICHIGAN CK. (T) DURING STUDY PERIOD

Environmental Factor	SC	T
Alkalinity	275-310 ppm	300-360 ppm
Carbon Dioxide	2-23	3-18 ppm
Hardness, Ca	190-225 ppm	170-250 ppm
Hardness, Total	350-400 ppm	375-425 ppm
pH	7.5-8.4	7.7-8.3
Temperature	4-15°C	5-22°C

(BE, SR, SS) are confined to three or four dates. Consequently, information on seasonal changes is restricted to limited observations at four localities (F, K, SC, T) from either May or June, 1972 through April, 1973. *Batrachospermum boryanum* and *B. moniliforme* occurred in mixed populations at all four sites; consequently, reference to *Batrachospermum* in the ensuing discussion includes both taxa.

The Fontana population (F) grew in very hard water (Ca hardness $\leqq$ 250 ppm $CaCO_3$; total hardness 410 ppm $CaCO_3$), swift flowing stream 1-2 m across whose temtures ranged from 12°C in summer to 6°C in winter. Carbon dioxide levels varied from 2-23 ppm, pH from 7.8-8.4, and alkalinity from 330-390 ppm. The stream bottom was primary gravel. During most of the day the habitat was exposed to full sunlight.

When first discovered in June, 1972, *Batrachospermum* plants occurred in considerable numbers and reached lengths of up to 18 cm. By July, 1972, however, most of the plants had disappeared or were obviously moribund. Several plants (preserved as WJW 3936) appeared heavily calcified. The population disappeared entirely by August, and new adult gametophytes did not become apparent until December, 1972, when about a dozen plants up to 6 cm tall were discovered. By January, 1973, *Batrachospermum* had become the dominant alga in the stream with most plants averaging 3-6 cm in length. Throughout the remainder of the study period (ending in April, 1973), *Batrachospermum* maintained its dominance in the stream and plants gradually increased in size to 12-15 cm on the average.

Similar seasonal fluctuation in population levels also occurred at Koshwego Springs (K), where certain chemical and physical conditions differed considerably from those at Fontana. At Koshwego, the water was very soft (Ca hardness $\leqq$ 15 ppm $CaCO_3$; total hardness $\simeq$ 25-30 ppm $CaCO_3$), acid (pH varied from 6.2-7.0), and showed alkalinity readings of 12-34 ppm. Stream bottom varied from rocky to sandy to partially silty with *Batrachospermum* confined to rocky areas. At all times, the habitat was subjected to deep shade. In other respects the two localities appear more or less similar; at Koshwego, temperature varied from 12°C in summer to 1.0°C in winter and CO_2 levels fluctuated between 1 and 11 ppm.

In May, 1972, *Batrachospermum* plants up to 8 cm tall dominated the stream vegetation, but by mid-July they had become very moribund or had disappeared. Small (i.e., less than 2.5 cm tall) plants reappeared in considerable numbers in November, 1972, and dominated the stream vegetation throughout the winter. Noticeable increase in size occurred between February (average size under 2.5 cm) and March, 1973 (average size 6 cm). Severe flooding and silting of the stream occurred in late March and early April, 1973, and the *Batrachospermum* population was almost entirely destroyed.

At the remaining two stations (SC, T) *Batrachospermum* plants occurred throughout the year and formed the dominant component of the algal vegetation during much of that time. Both stations had environments (Table 3) similar to that at Fontana except that one (SC) was largely shaded throughout the day and the other (T) was exposed to full sunlight during most of the day. In addition the latter (T) had summer temperatures of 18-22°C or 5-10°C higher than at the other hard water localities.

Immediately below the spring from which Scuppernong Creek originates, *Batrachospermum* plants constituted the dominant form of vegetation. Within 100 m, however, angiosperm vegetation became dominant and the *Batrachospermum* population consisted only of scattered plants. During winter months most plants encountered were 4-6 cm long and during summer they were 8-10 cm long; one 15 cm tall plant was encountered.

The Tichigan Creek population of *Batrachospermum* dominated the macroscopic vegetation throughout the year. Summer plants generally did not exceed 10 cm in length; winter plants all (i.e., December-April) were enormous in size and reached lengths of up to 25 cm. The very large size of these individuals as compared to the other winter populations studied could not be accounted for on the basis of the physical or chemical parameters examined during the study.

The above observations suggest that different populations of *Batrachospermum* (at least in Wisconsin streams) may either produce mature gametophytes throughout the year (SC, T) or show seasonal variation with an absence of mature plants from mid-summer to late fall (F, K). They also suggest that maximum vegetative development can occur in spring (F, K), summer (SC), or winter (T). Previous American studies (Dillard, 1966, Minckley and Tindall, 1963, Rider and Wagner, 1972) all reported definite seasonal fluctuations in *Batrachospermum* populations with a disappearance of plants in summer and a reappearance in fall. Yoshida (1959), however, makes mention of both seascnal and year-round populations of *Batrachospermum* in Japanese streams.

Various attempts have been made to account for seasonal fluctuation in population levels in terms of temperature changes, changes in light intensity, and differences in current velocity (see Dillard, 1966, Minckley and Tindall, 1963, Rider and Wagner, 1972, Yoshida, 1959). The results of the Wisconsin study, however, indicate that mature plants and maximum vegetative development can occur under both low and high light intensities and under both summer and winter temperatures. Therefore, other factors, perhaps genetic, appear to be involved in determining why different populations of the same species either persist year round or show seasonal fluctuations. No relationship to current velocity has been observed in this investigation.

The apparently consistent occurrence of *Batrachospermum* in the headwater areas of spring-fed streams likewise requires further investigation. Minckley and Tindall (1963) suggest that the availability of unbound carbon dioxide may be a controlling factor (their stream reportedly has super-saturated CO_2 levels), but the relatively low CO_2 levels found during this study again suggest that other factors may be involved, and additional study appears warranted.

SUMMARY

The occurrence and some ecological aspects of *Batrachospermum* in southeastern Wisconsin streams have been investigated. *Batrachospermum boryanum* (newly reported for Wisconsin), *B. moniliforme*, and *Batrachospermum* sp. occurred in 6.4% of the localities visited and were found in both alkaline, hard water and acid, soft water environments. Depending upon the population, mature plants persisted throughout the year or disappeared in summer and fall, and they showed maximum vegetative development in spring, or summer, or winter. The seasonal behavior does not appear to be correlated entirely with changes in light intensity or temperature. Likewise the apparent occurrence of *Batrachospermum* near the headwaters of spring-fed streams apparently cannot be explained solely on the basis of greater availability of unbound carbon dioxide in these habitats.

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